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ABSTRACT

This paper presents the Bouncing Ball Experiment which models quadratic and exponential functions, and the Hot Rod Races activity that explores velocity and acceleration. Activities include directions for the use of TI-82 and TI-83 calculators. (YDS)

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BOUNCING BALLS AND HOT ROD RACES

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March 17 - 19 2000

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GETTING STARTED

Resetting the calculator:

We need to begin by resetting the calculator. To do this, press

2nd MEM then select 7.Reset. On the next screen: RAM Select 1:All RAM then select 2:Reset.

This will clear out anything that previous users of the calculator have done.

Memory Requirements:

In order to run the Ranger program, the calculator must have at least 17,500 bytes of RAM free.

Note: If you have programs that you want to save, then begin by Archiving all programs by doing the following steps:

2nd MEM Then select 2: MEM MGMT/DEL Then 7:PRGM. Then press ENTER to insert * by each program. The * symbol shows that the program has been archived. To Unarchive after using the CBR programs, repeat the process exactly.

Using the TI-82 or TI-83:

If you are using the TI-82 or TI-83, you must delete all

programs. Then link the CBR and the calculator.

Follow these steps:

1. On calculator, press: 2nd, LINK RECEIVE ENTER.
2. The calculator will say: Waiting...
3. Press the button on the CBR that says "82/83" The program: RANGER will then be transferred to the calculator.

Regression:

1. The first time the TI-83 Plus is used, you must turn on the feature that gives the correlation coefficient of the regression line. To do this, press 2nd CATALOG and scroll down until you reach Diagnostic ON. Press ENTER ENTER until the calculator says: Done.

2. Press STAT and select 1: EDIT You will see L1, L2, and L3 on your screen. There are 3 other lists that can be accessed by using your right arrow key.

3. If there are numbers in the lists that need to be cleared, arrow up to the name of the list, press CLEAR then ENTER.
4. To enter your data, choose L1 as your x-list and L2 as your y-list. After each entry, press ENTER.
5. After entering your data, press STAT CALC then select the type of regression you need. As long as you are using L1 as the x-list and L2 as the y-list, it is not necessary to specify the lists. If you are using any other lists, it is necessary at this point to type in the lists you are using: for example, if you want to use L5 as the x-list and L6 as the y-list, type: LinReg(ax+b) L5,L6 then ENTER. The calculator will then give you the regression equation.

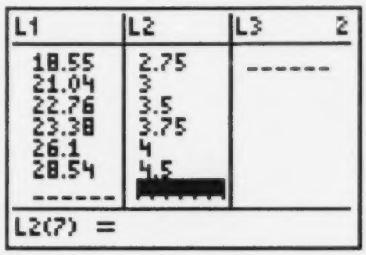
Practice :

To see a simple example using linear regression, we will work through this problem together.

A student who works as a waiter records the cost of meal and the tip left by couples. Since the tip is a function of the cost of the meal, we will record the cost of the meal in L1 and the tip in L2.

Couple 1: Meal cost $18.55 Tip was $2.75
Couple 2: Meal cost $21.04 Tip was $3.00
Couple 3: Meal cost $22.76 Tip was $3.50
Couple 4: Meal cost $23.38 Tip was $3.75
Couple 5: Meal cost $26.10 Tip was $4.00
Couple 6: Meal cost $28.54 Tip was $4.50

When entered into List 1 and List 2, the display looks like this:

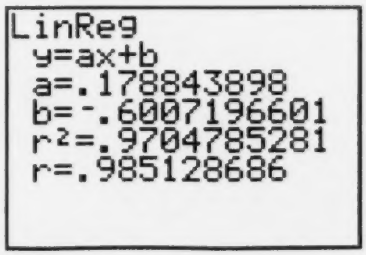


Then press STAT CALC and select 4:LinReg

The regression equation is:

$y = .18x - .60$

The correlation coefficient is the r value: r = .9851.



Bouncing Ball Experiment
Modeling a Quadratic Function

A quadratic function can be modeled by recording the height of a ball as a function of time. This can be modeled using the CBR to record the data.

Materials: TI-83 Plus Calculator, CBR, Linking Cord, Ball

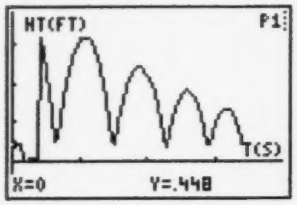
Procedure:

1. Press APPS. Choose #2 CBL/CBR. Press any key. Choose #3 RANGER. Press ENTER. Choose #3 APPLICATIONS at the Main Menu. Choose #2 Feet as the units.

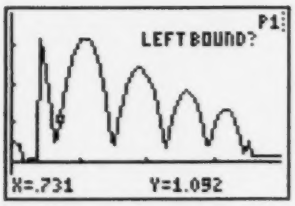
2. Connect your calculator to the CBR with the linking cord.

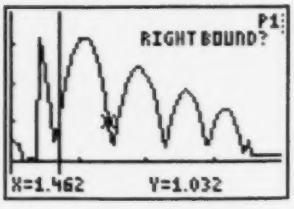
3. Choose #3 BALL BOUNCE. Follow the directions on the screen. You only need one clear bounce. If the ball bounces away from the CBR, follow it. However, be careful to keep the CBR at the same height.

4. After the CBR is finished recording data hit ENTER.
You will see the message: "Transferring...."
You will then see the graph on the calculator screen.
The graph should look similar to the graph to the right.
If your graph does not contain one clear bounce, hit ENTER then #5 REPEAT SAMPLE.

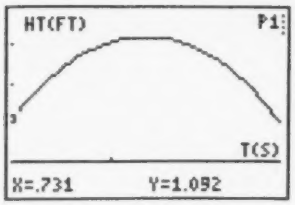


5. When you have a graph with at least one clear bounce, press ENTER, which will take you to the PLOT MENU. Choose #4 PLOT TOOLS. Choose #1 SELECT DOMAIN. Set your left bound and right bound on either side of the parabola on the graph by moving the cursor and pressing ENTER as shown on the example below.



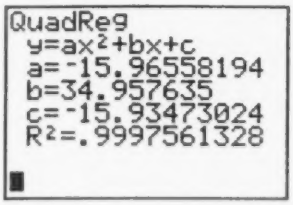


The calculator will say "analyzing..." and then will show just the part of the graph you have selected as shown to the right. The coordinates of the points are stored in List 1 and List 2, that is time in List 1 and height of the ball in List 2.



6. Hit ENTER which carries you back to the MAIN MENU. Select #7 QUIT. The calculator will say Done.

7. Use quadratic regression to find the equation of the graph that best fits the data and you will see an equation as shown on the right. Record your equation here. _____



8. Press Y= on your calculator and enter the regression equation you found for y1 to see if the graph is a good fit.

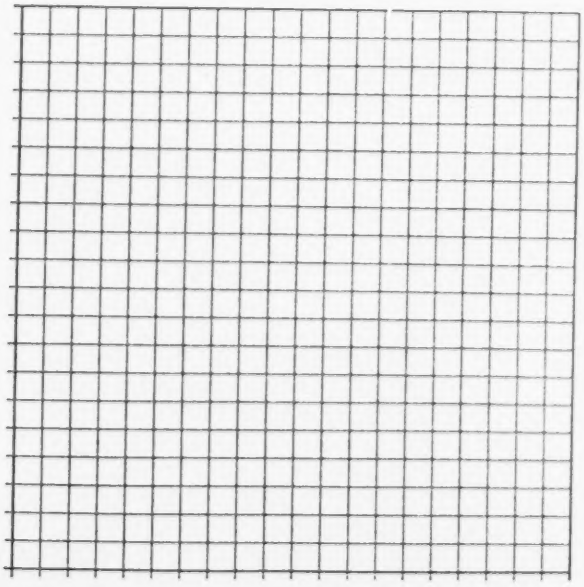
9. What is the vertex of the parabola?

10. What is the height of the bounce and when did it occur?

11. What are the x-intercepts of the function?

12. Fill in five points on the table that are on your quadratic equation and make a sketch on the graph provided , showing vertex and x-intercepts.

X (Time)	Y(Distance



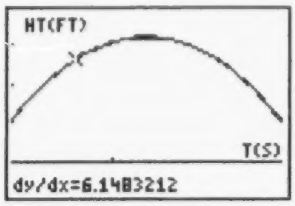
13. The equation of motion of freely falling bodies is

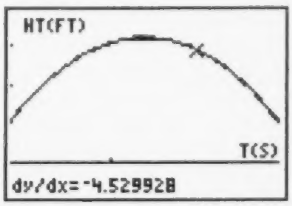
$$h = -\frac{1}{2}gt^2 + v_0 t + h_0$$

where g is acceleration due to gravity, v_0 is the initial velocity, and h_0 is the initial height.
According to your equation, what is the value for g? _____
The values of b and c are not the initial velocity and height in your regression equation because the first or initial bounce was not used.

14. The velocity of the ball is (change in distance) divided by (change in time). Is the velocity of the ball constant?

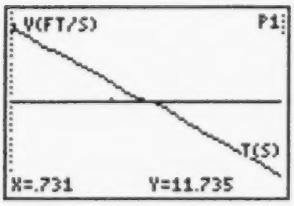
15. Trace on the regression equation on your graph and use 2nd CALC #6 dy/dx to find the velocity of the ball at several points on the graph as shown on the graphs below. Where is the velocity the greatest? The least? Show this on your graph.





16. Press APPS. Choose #2 CBL/CBR. Run the RANGER program.

17. Choose #4 PLOT MENU, choose #2 VEL-TIME. See the graph below. Is that what you would have expected to find?



Bouncing Ball Experiment
Modeling an Exponential Function

According to Physics textbooks, when a ball is bounced, for a given ball and height, the rebound height decreases exponentially for each successive bounce. We will test this hypothesis using a CBR.

Materials: TI-83 Plus Calculator, CBR, Linking Cord, Ball

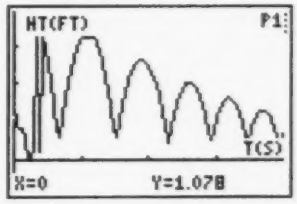
Procedure:

1. Press APPS on the TI-83 Plus Calculator. Choose #2 CBL/CBR. Press any key. Choose #3 Ranger. Press ENTER. Choose #3 APPLICATIONS at the Main Menu. Choose #2 Feet as the units.

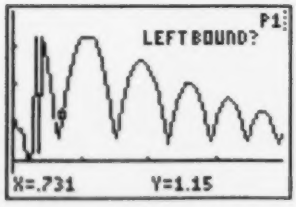
2. Connect your calculator to the CBR with the linking cord.

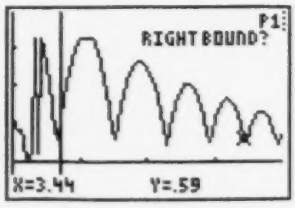
3. Choose #3 BALL BOUNCE. Follow directions on the screen. You will need at least four good bounces. If the ball bounces away from the CBR follow it but be careful to keep the CBR at the same level.

4. After the CBR is finished recording the data, hit ENTER. You will see the message "transferring..." You will then see the graph on the calculator screen. If your graph does not contain four good bounces as shown on the graph to the right, press ENTER again the #5 REPEAT SAMPLE.



5. If your graph does contain at least four good bounces, hit ENTER, which will take you to the PLOT MENU. Choose #4 PLOT TOOLS. Choose #1 SELECT DOMAIN. Set your left bound and right bound on either side of the four good bounces on the graph by moving your cursor and pressing ENTER as shown on the graphs below. The calculator will say "analyzing..." and then will show just the part of the graph you have selected.

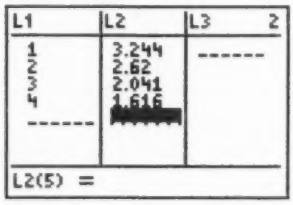




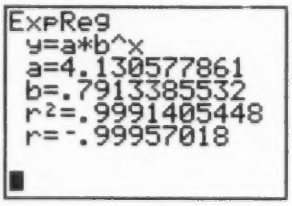
6. Using TRACE, estimate the y-coordinate of the highest point of each bounce. Record this on the following worksheet.

7. Press ENTER. Choose QUIT.

8. Go to STAT and EDIT and record the number of the bounce in List 1 and the height of the bounce in List 2 as shown on the graph below for the example.



9. Find the exponential regression equation for the data as shown below for the example. Record the equation on the following worksheet



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WORKSHEET

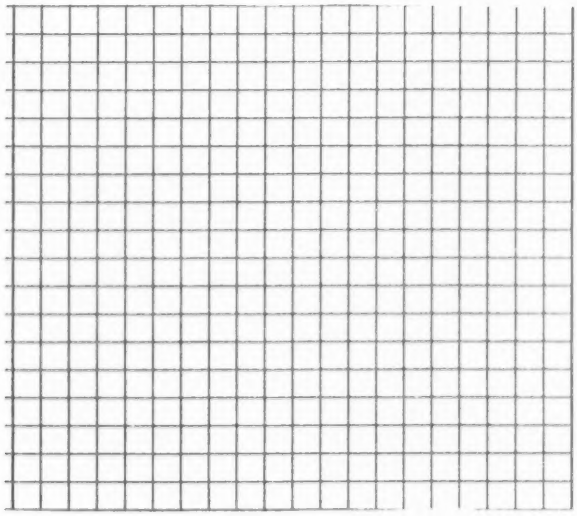
1. **Record the data in the table.**

Bounce Number (L1)	Height (L2)

2. **Record the Exponential Regression Equation and the correlation coefficient for your data.**

_____ r = _____

3. **Plot the data points and the regression equation on the graph below.**



4. **Interpret and Predict:**

a) According to your exponential regression equation, from what height was the ball dropped?

b) Each bounce was _____% of the previous bounce.

c) How high would the ball rebound on the 10th bounce?

d) After how many bounces would the ball rebound to a height of 6 inches?

HOT ROD RACES

EXPLORING VELOCITY AND ACCELERATION

Objectives:

1. To see the relationship between distance, velocity, and time.
2. To see the relationship between velocity, acceleration, and time.
3. To see who has the "hottest" car.

Materials Needed:

CBR, cars, TI-83 Plus, ramp, ruler.

Procedure:

Organize class into groups, so that each group has at least 2 cars, 2 calculators, a ramp, a ruler, and a CBR.

1. Set up the ramp so that the elevation is 12 inches.
2. Connect calculator to CBR with linking cord.
3. Press APPS then select 2: CBL/CBR. Press ENTER. Select 3: RANGER.
4. Under MAIN MENU, select 1: SETUP/SAMPLE.
5. Set display to look like this:

Real time:	no
Time(s):	2
Display:	Dist
Begin on:	Trigger
Smoothing:	None
Units:	feet

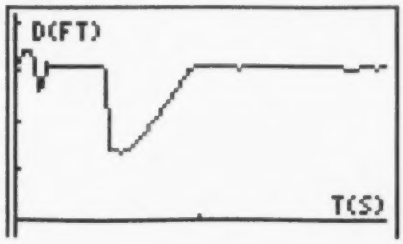
(To change entries on display, highlight the word and hit ENTER.)

6. Place car at the upper end of the ramp. Hold the CBR so that it is pointed down the ramp, with the head perpendicular to the ramp.

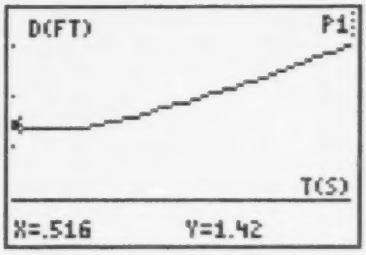
Note: The CBR ideally should be located about 18 inches from the car. However, this is difficult to arrange unless you have a longer ramp. We will disregard the first part of the graph.

7. Arrow up to START NOW and press ENTER. Be sure calculator is firmly linked to the CBR. Press trigger on the CBR first, then release the car.

   Your display should look like this. If necessary, repeat sample.



8. Now go to PLOT MENU, and select 4: Plot Tools.
9. Under Plot Tools select 1: Select Domain
10. Use your arrow keys to select a left and right bound of the graph, selecting the part of the graph that shows the car in motion. The calculator will say : Analyzing... Your display should look like this:



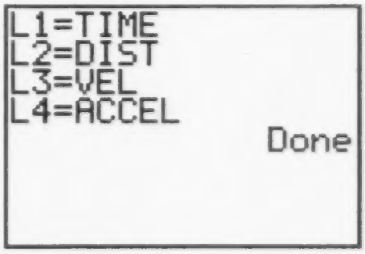
10. Using Trace, find the coordinates of the end points of your graph. Use these points to find the average rate of change of the graph. On this graph, the lower end point is (.516, 1.42) and the upper end point is (.946, 2.997). The rate of change or average velocity is 3.67 feet/sec.

Record the coordinates of your endpoints on the attached worksheet. Find average velocity and record this on your worksheet.

$$a.v. = \frac{\Delta dis\,tance}{\Delta time}$$

10. Now go back to Main Menu and choose 6:QUIT. The calculator will show that it has stored the data as shown:

11. Using Quadratic Regression with L1 and L2, we can find an equation that approximates our data. For this example,

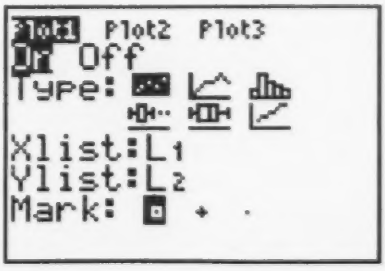


$y = 7.7x^2 - 7.23x + 3$

$R^2 = .9927$

12. Now go to STAT PLOT and turn on Plot 1.

Set your window to look like this:



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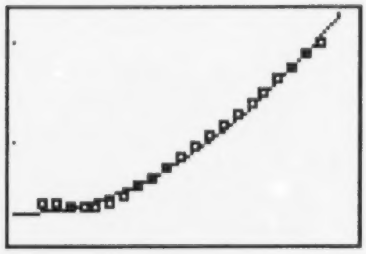
Now press Y= and type in your regression equation.

To automatically set your window, use ZOOM 9.
You can see that the regression line is a good approximation of the data.

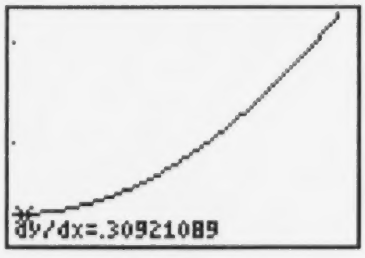


Finding Average Acceleration:

We now have an equation that approximates our data.
We can use this equation to find average acceleration.

1. Go to STAT PLOT and turn off Plot 1. Leave your window as it is.

2. Press GRAPH. Now press 2nd CALC then choose 6:dy/dx.
Using this key, we can find the velocity at any point of our graph. Using your arrow keys, find the velocity at the lowest point of your graph.
Repeat the process to find the velocity at the highest point of your graph.
For this example, velocity at the lowest point is .3092, where x = .4895. The highest velocity is 7.6652, where x = .9672.



Since acceleration is defined as:
Δ velocity / Δ time, our average acceleration is 15.9 ft/sec^2.

For your car, record the velocity at the two endpoints, then find average acceleration. Record this on the data sheet.

Now, repeat the process for the second car.

DATA WORKSHEET

RECORD THE COORDINATES OF THE ENDPOINTS OF YOUR DISTANCE VS. TIME GRAPH:

CAR 1		CAR 2	
(X) TIME	**(Y) DISTANCE**	**(X) TIME**	**(Y) DISTANCE**

Find the average velocity:

Car 1_____ **Car 2**_____

RECORD THE VALUES FOR TIME AND VELOCITY (dy/dx) FOR TWO POINTS OF THE GRAPH OF THE REGRESSION LINE:

CAR 1		CAR 2	
(X) TIME	**(Y) (dy/dx)**	**(X) TIME**	**(Y) (dy/dx)**

Find average acceleration:

Car 1_____ **Car 2**_____

EXTENDING:

1. When finding acceleration, does it matter which two points we choose?

Try using 2 other points that are not end points of the graph.

2. Is there a relationship between the coefficient of the x^2 term and the acceleration?

3. What would happen if the ramp were at a different height?

4. What would you expect the coefficient of the X^2 term to be if the ramp were vertical?